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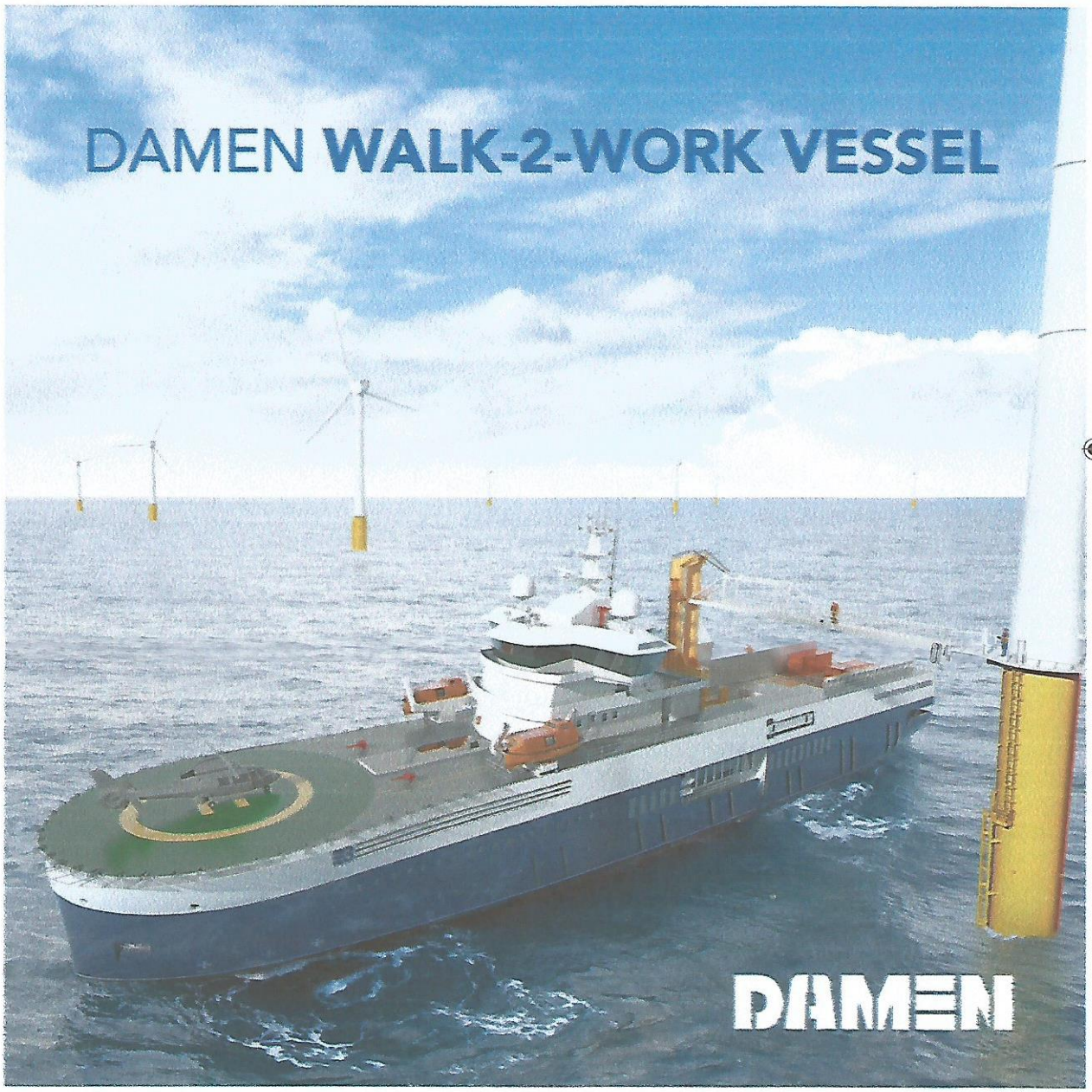

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Keel bolt integrity failure: the hidden killer

The May 2014 capsizal of the yacht *Cheeki Rafiki*, a tragedy which led to four fatalities, could well be linked to keel bolt integrity failure, argues Capt Ed Geary

On May 4th 2014, the British-registered Beneteau First 40.7 *Cheeki Rafiki* sailed from Antigua in the West Indies, bound for Southampton, England. On the 16th of May she made the last contact with her owners and then disappeared. After an extensive search by the maritime assets of the UK, the US and Canada, the vessel's overturned hull was eventually found, 1,000 miles off the eastern seaboard of the US.

Following the loss of *Cheeki Rafiki*, a number of extemporized observations and speculative analyses of this tragic loss – put forward by nautical pundits and other arm-chair experts – were reported, by both electronic and print media, as an unfortunate accident. However, this wasn't an accident.

The loss of the yacht and the tragic death of her four sailors were, in my opinion, the results of third party incompetence and negligence and this incident was preventable. For this reason, those who were responsible for the proper care and maintenance of the vessel should be identified and held accountable to ensure something like this doesn't ever happen again.

Code of compliance

At one point in her recent history, *Cheeki Rafiki* was inspected and coded under the Small Commercial Vessel Compliance Document (SCV) by a certifying authority approved by the UK Maritime and Coastguard Agency (MCA). On the last pages of the SCV, the MCA requires an 'external evaluation' which includes the inspection and confirmation of the integrity of the keel-to-hull join. Because of their locations, access to keel bolts is frequently limited and, unless the keel is visually seen to be separating from the hull, surveyors rarely confirm keel bolt integrity and simply tick the keel-to-hull join as being 'OK'.

If a keel falls off, the vessel will capsize, which is why the keel-to-hull join and the integrity of the keel bolts must always be checked and supported by a written confirmation, on a regular basis. The record of the surveyor's inspection and confirmation of keel bolt integrity must be carried out each time the vessel is hauled and particularly during its initial or intermediate code of compliance inspections. Simply ticking the box as 'OK' is not acceptable.

Irrespective of whether the surveyor finds the internal nuts and/or securing plates bright and shiny or rusted and corroded, keel bolt integrity must, and can be, easily confirmed. Using a calibrated torque wrench with the keel resting on-the-hard, the keel bolts should be individually checked to ensure they are tight and torqued to the builder's original specifications. If the calibrated wrench indicates the original PSI torque is present, the keel-to-hull join, under external examination, can be marked as 'OK', with the written confirmation recorded on the SCV document of compliance.

If the required torque is not achieved, and any of the keel bolts are found to be loose or turn when pressure is applied, the vessel would fail the MCA SCV examination. Only after the keel bolt deficiency was corrected could a new date be scheduled for a subsequent examination. In addition to the use of a torque wrench, should the attending surveyor have thermal imaging capabilities (ie, an infrared camera) this technology can be an important survey/inspection tool in determining the condition of the keel-to-hull join and in the confirmation of keel bolt integrity.

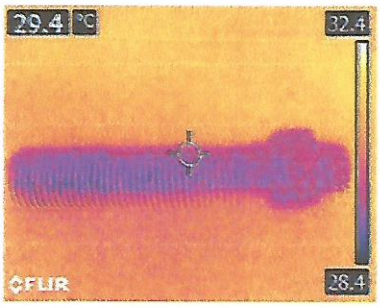
Keel bolt corrosion

Essential to the thorough investigation being conducted by the MCA's Marine Accident Investigation Branch (MAIB) into the keel failure and subsequent loss of *Cheeki Rafiki* will be a careful analysis of the vessel's previous surveys and the file held by the certifying authority that had issued her document of compliance. Shortly after the loss, the *Cheeki Rafiki* file was surrendered by the certifying authority. While not being privy to the contents of the SCV document of compliance submitted by this particular certifying authority, I am confident that the MAIB investigation will find that the SCV does not contain a written record in confirmation of the integrity of the keel-to-hull join, but simply displays a tick mark as being 'OK'.

It is interesting to recall *Cheeki Rafiki* grounding on Gurnard Ledge in the Solent, only a few weeks before sailing to Antigua. Even after a hard grounding and waiting for the turn of the tide before being re-floated, *Cheeki Rafiki* wasn't hauled into Southampton for an inspection of the damages.

From an insurance perspective, in dealing with claims and losses, the determination of proximate cause or *causa proxima* is a fundamental and important element. The *causa proxima* in the loss of *Cheeki Rafiki* that led to the untimely death of the crew was, in my opinion, a direct result of the vessel's unseaworthiness due to keel bolt corrosion. In view of the UK House of Lords ruling in the Manifest Shipping v. Uni-Polaris case relating to 'Blind-Eye Knowledge of Unseaworthiness', it will be interesting to see how *Cheeki Rafiki*'s insurers will react.[1]

Considering the photographic evidence of leakage around the rusted keel bolts, low levels of seawater had clearly been present in the bilges for some time. During the passage to Southampton, with *Cheeki Rafiki* now encountering the turbulence of the north Atlantic, the skipper, obviously concerned, contacted the owner to report



Pictures A+B: while still in place, the upper shaft and nut of the keel bolt displayed major corrosion (above). Following its removal, the extensive corrosion was further confirmed by thermal imagery (right)

that the yacht was taking on water and requested permission to divert to the Azores; he didn't report a collision or having struck anything. The noticeable increased flow of water reported by the skipper was incurred and began as the loose keel bolts continued to lose integrity and the keel began separating from the hull.

The loose-fitting keel-to-hull join appears to have been leaking water for some time, as evidenced by the rust stains on the external hull apertures, the result of crevice corrosion and metal fatigue. When the corroded keel bolt nuts experienced total failure, this allowed the keel to separate from the hull and fall to the bottom of the ocean. Tightened keel bolts don't fail, loose ones do. When total failure occurred the keel fell free, causing the external damage to the hull laminates amidships.

The laminate damage which was limited to the hull/keel join (amidships) was sustained after the forward and aft keel bolt nuts failed and the remaining amidships keel bolts, now holding the entire weight of the keel and being unable to do so, failed, ripping the surrounding fibreglass from the hull as it dropped from the vessel. When the fore and aft keel bolts nuts failed the keel bolt shafts would have remained in the keel as it fell free. The keel bolts and nuts amidships, being unable to bear the entire weight of the keel, pulled through the hull, resulting in the damage to the hull laminates.

The 'collision' myth

While tendering no evidence to support their theories, some 'experts' have speculated that *Cheeky Rafiki*'s keel may have struck a semi-submerged object, such as a container. When a fin keel strikes a semi-submerged obstacle, the hull will sustain damage either forward, aft or both forward and aft of the keel-to-hull join. With no impact or laminate damage to the hull forward or aft of where the keel was attached, there is no basis to support the theory of striking a submerged object. The blade rudder was also undamaged. The undamaged apertures of the forward and aft keel bolts, and their clean separation, indicates the keel bolts and securing nuts failed as a result of microstructural degradation/metallurgical deterioration, resulting in the loss of the keel (see pictures A and B).

The loss of keel bolt integrity can occur due to crevice corrosion of the lower shaft, or as a result of corrosion of the upper shaft and the nut whose sole purpose is to tightly secure the keel against the hull. For this reason, when conducting MCA code of compliance inspections or even a basic condition and valuation survey, surveyors must always insist that the correct torque of the keel bolts be confirmed in accordance with the manufacturer's specifications, which is easily verified using a calibrated torque wrench.

During *Cheeki Rafiki*'s 640 nm voyage north, the approximately 3.5tonne keel was only partially held against the flat hull surface because of the defective keel bolt nuts; this allowed movement, a swinging motion of the keel and the ingress of water which was reported by the captain. Unbeknownst to the crew, because of the turbulent sea state and parametric rolling that aggravated and accelerated ultimate failure, the keel would have been subjected to an increased side-to-side swinging motion before it was eventually pulled away from the hull.

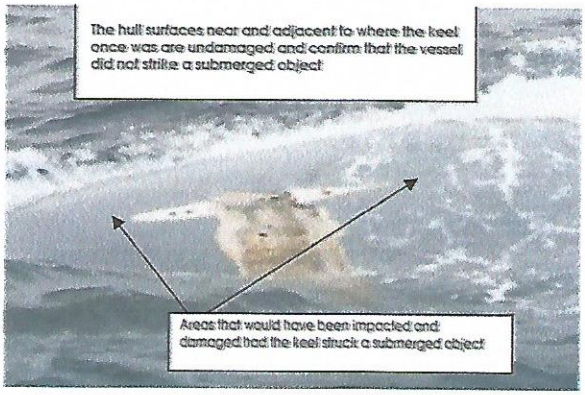
The photograph of *Cheeky Rafiki*'s inverted hull (see page 17) silently speaks volumes and confirms the keel bolt failure that led to the loss of the keel, resulting in the immediate change and rise of the vertical centre of gravity (VCG) and capsizing. The crew were experienced sailors so they would have been wearing life-vests, safety lines, and, in that area of the Atlantic, were probably also wearing thermal suits. When the keel parted from the hull at night, in the turbulent seas and violent winds, the four-man crew would have had little time to avoid being dragged under by the sails and/or standing rigging when the immediate change of the VCG caused the hull to roll. It's possible, but sadly I doubt if the bodies will ever be recovered.

Navy surface divers found the liferaft secured on the stern of the vessel, which may have been easily reached as the vessel capsized but it did not inflate as a result of being improperly lashed and/or the painter not being properly secured to a fixed point. If a painter line is left loose or not properly secured, the liferaft won't activate, can't deploy and goes down with the vessel – which is exactly what happened in this case.

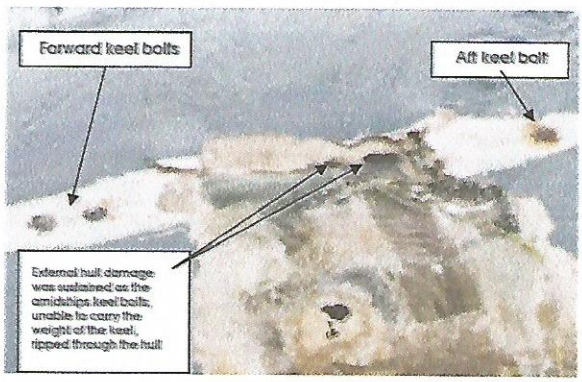
Pattern of negligence

This tragedy should not have happened. I believe that, through no fault of the crew, *Cheeki Rafiki* was sent to sea in an unseaworthy condition and those responsible should be held accountable. The prevailing pattern of failing to conduct proper surveys was further confirmed during a recent MCA code of compliance inspection of a large relatively new sailing yacht which was also approved for SCV coding by the same certifying authority. The vessel was scheduled to sail from California to Newport, Rhode Island, then on to Palma, Mallorca, in the Mediterranean. During the vessel's intermediate SCV survey in California, the keel bolts were found to be loose.

There's no doubt that, in conducting a survey, owners will generally express their displeasure in having to undertake the tedious task to confirm keel bolt integrity



The light coloured threads are undamaged, while the rusted/red upper threads leading to the nut are not sharp and had become rounded and smooth as a result of corrosion



because, historically, with previous MCA inspections or condition surveys, this has never been a requirement of underwriters or enforced by the MCA.

Captains and owners are often oblivious to or choose to ignore the fact that defective keel bolts put sailors' lives at risk, and this is why their integrity must always be confirmed. If the keel bolts are tight, no problem; if they're not, it's important to find out why. Confirmation of keel bolt integrity is a bit like being pregnant – you either are or you're not; there's no middle ground.

During an inspection, when the surveyor sees a separation of the keel/hull join or obvious corrosion of the nut and/or backing plates as a result of low levels of water in the bilges (which is normally the case), the compliance inspection or survey should immediately focus on keel bolt integrity.

During a recent claim inspection of a 13.4m sailing yacht that had lightly grounded off the Mediterranean coast, the hull was found to have sustained only minor damage, but major corrosion was in evidence on the keel bolt nuts. The laminate damage to the hull was repaired and the shipyard was instructed to remove the keel bolts for inspection. As shown in the picture below, the upper threads of the keel bolts and their securing nuts were totally wasted; because of their condition they would soon fail, allowing the keel to part from the hull, causing an immediate change in the VCG and capsizing, which is precisely what happened in the loss of *Cheeki Rafiki*.

Had the yacht continued on her voyage to the Caribbean with corroded keel bolts, the weight of the keel could have pulled the keel bolt through the hull aperture, causing the keel to separate from the hull.

The bottom line is this: the US Coast Guard (USCG) and the RNLI have self-righting power boats but, unless you own a self-righting fin-keeled sail boat, always insist that keel bolt integrity be confirmed in any survey. **SBI**

The rusted backing plates, while structurally sound, displayed surface corrosion but would not have had any restraining effect when the corroded keel bolt nuts failed, releasing the keel

Footnotes

1:See http://www.publications.parliament.uk/pa/ld200001/ldjudgmt/jd010118/manife1.htm for more information

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